CLIMATE AND AIR QUALITY OF THE LAKE TAHOE REGION

A Guide to Planning

Prepared for
Tahoe Regional Planning Agency
and
Forest Service, U. S. Department of Agriculture

South Lake Tahoe, California
September 1971

ACKNOWLEDGMENTS

Establishment of the Tahoe Regional Planning Agency was consented to by the Congress through enactment of Public Law 91-148. On March 19, 1970, the governors of Nevada and California signed the proclamation that proclaimed creation of the Tahoe Regional Planning Agency. Since the authorized staff of the Agency was small, it enlisted help from several committees composed of technical specialists and other citizens concerned with resource conservation and orderly development of the Tahoe environmental resources.

The planning effort has been aided greatly by generous cooperation from numerous federal, state, county, and municipal agencies and from several colleges and interested private individuals. Cooperating agencies included:

Federal:

Department of Agriculture: Forest Service; Soil Conservation Service

Department of Commerce: Environmental Science Services Administration

Department of Defense: Army Corps of Engineers

Department of Interior: The Bureaus of Mines, Outdoor Recreation, Reclamation, Sport Fisheries and Wildlife; Federal Water Quality Administration; and the Geological Survey

Department of Transportation: Coast Guard; Federal Highway Administration; Federal Aviation Administration

State:

California: The Resources Agency of California; State Department of Public Health

Nevada: The Nevada Department of Conservation and Natural Resources

County and Municipal:

Carson City, Douglas, and Washoe Counties, Nevada; El Dorado and Placer Counties and City of South Lake Tahoe, California

Schools:

Foresta Institute; Sacramento State College; Tahoe College; University of California at Berkeley and Davis; University of Nevada; Desert Research Institute

Any publication that compiles and presents information from so large and disparate a group of contributors as this one does is susceptible to error, inconsistency, and omission. Sustained effort has been made to avoid these flaws; but if it has failed occasionally, the reader's forbearance is humbly solicited.

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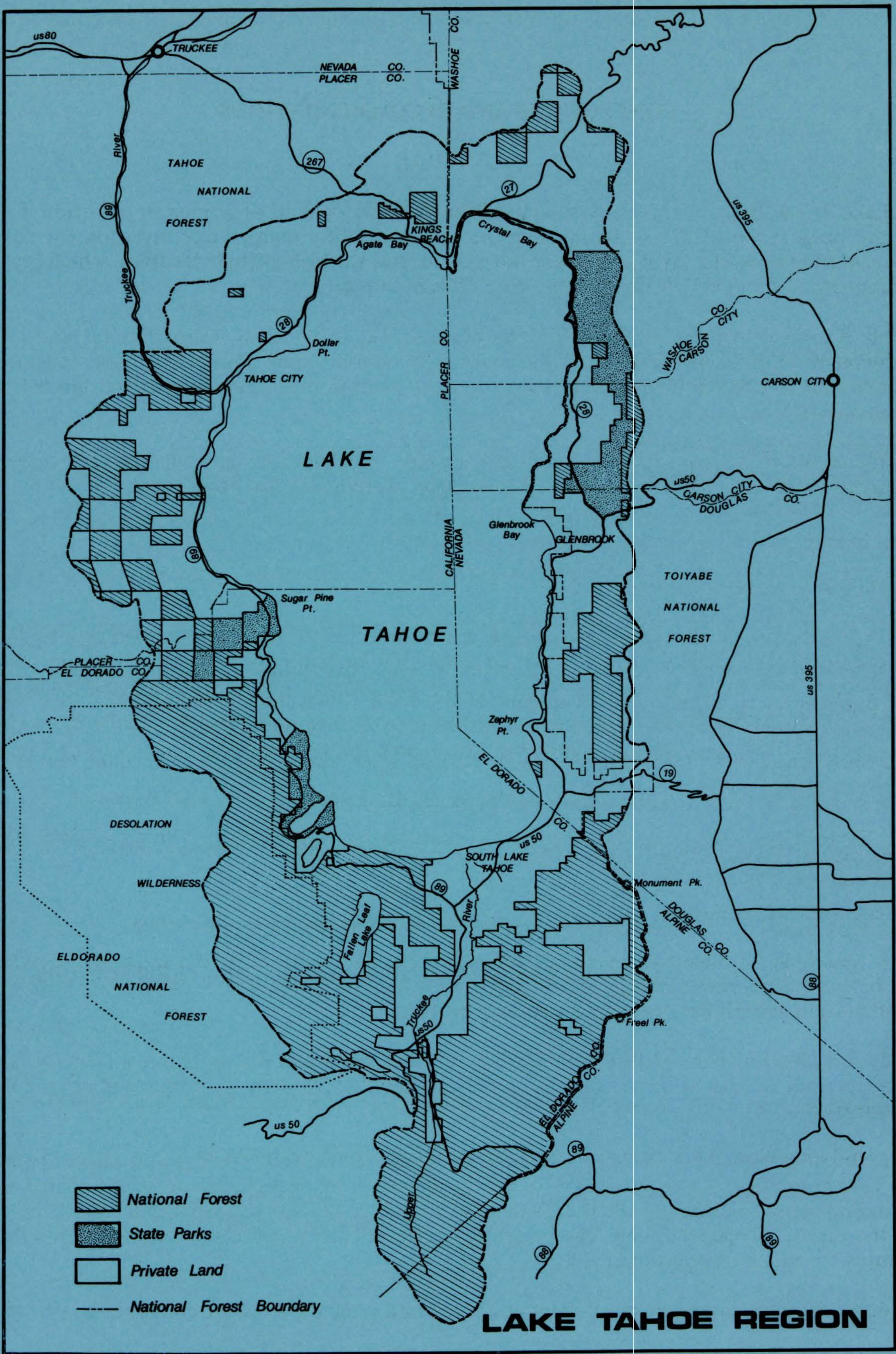

LAKE TAHOE REGION
National Forest
State Parks
Private Land
National Forest Boundary
LAKE
TAHOE
us80
TRUCKEE
NEVADA CO.
PLACER CO.
WASHOE CO.
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Truckee River
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CONCLUSIONS AND RECOMMENDATIONS

GENERAL

The Lake Tahoe Basin is especially susceptible to the development of serious air pollution. Factors are: the bowl shape of the air basin; frequent occurrence of a temperature inversion (or lid) that traps pollution in a thin layer of air near the ground; and the high-altitude location, which increases the intensity of the sun's rays on noxious chemicals in the air.

Climate is critical to the planning of orderly development of the Lake Tahoe Region, and all land development projects should take into account such factors as the semiarid climatic stress on the lower east shore and on south-facing slopes, and the potential for extremely severe rain and snow storms and snow melt periods.

Additional research plus monitoring of temperature, precipitation, and air currents (especially vertical currents) are essential to improved long-range planning for the Basin.

SPECIFIC

Climate and Land Development

1. Land developers should obtain records of precipitation for the areas they propose to develop and should obtain reliable estimates of available soil moisture, evaporative stress, and climatic hazards (e.g., high intensity summer rainstorms) before clearing of vegetation and making proposals for subsequent revegetation.

2. Snow pack should be estimated from climatic records and taken into account before roads and structures are built.

3. Wind intensity and direction should be estimated, and its effect on blowdown should be determined prior to clearing of vegetative cover.

Abatement of Air Pollution

1. Location of highways, parking lots, residences, and commercial and industrial facilities on land below the estimated level of inversion (i.e., about 6,700 feet) should be done only with realization that these contribute directly to the smog problem.

2. Exposure of bare ground must be kept to the minimum during seasonal (chiefly fall and spring) periods of high winds so as to prevent blowing dust. No long-term baring of ground should be permitted.

3. Incineration and open burning should be strictly controlled – perhaps prohibited before 11 a.m. in the summer and on calm days in winter. Problems of air pollution must be weighed against fire hazard when considering the use of burning to reduce the fuel potential of matured vegetation and the timing of open burning. The present practice of "morning burning" conflicts directly with attempts to reduce air pollution.

4. Construction projects must water or cover bared ground during the construction period.

5. Batch plants, incinerators, and other smoke producers can and must be controlled by enforcing standard air pollution control regulations governing visible emissions (darkness and opacity measurements as covered in California and Nevada control regulations).

6. Consideration should be given to limiting traffic into the Lake Tahoe Basin on days when air pollution is severe.

7. An air pollution warning system should be established for the Lake Tahoe air basin.

8. Consider alternate transportation methods to the internal combustion engine – especially for public transportation – essentially absent at present.

9. The California portion of the Lake Tahoe Basin is now assigned to the Sacramento Air Basin. The entire Lake Tahoe Basin should be incorporated into an interstate air basin so that regulations could be uniform throughout, and so that regulations could be specific to the situation at Lake Tahoe without having them necessarily apply to other out-of-basin areas where the type or stringency of regulations might not be appropriate.

10. The agency (or agencies) responsible for air pollution control (proposed in Recommendation 9) should quickly act to translate the general findings of this report into specific, enforceable standards.

Climate and Monitoring of Pollution

1. A comprehensive continuing program of description and monitoring of air pollution should be established. Not only should such standard weather characteristics as rainfall, wind speed and direction, etc. be measured, but other phenomena such as vertical air currents and subsidence must be included. Components and effects of pollution must be evaluated, and this must be done more intensively than is required in less sensitive urban areas.

2. The relation of climate and air pollution to other aspects of regional environment should be assessed. The contribution of windblown dust to the degradation of the water of Lake Tahoe is a priority topic. Other critical items are damage to natural vegetation and the incidence of obscuration of scenery.

INTRODUCTION

General Features of the Lake Tahoe Planning Area

Lake Tahoe and the mountainous timber-covered basin immediately surrounding it provide one of the most beautiful environments in the Sierra Nevada and in the nation. The Lake itself, an irregular oval about 22 miles long by 12 miles wide, covers 191 square miles; it occupies a deep depression between crests of the Sierra Nevada and Carson ranges. Since its surface is 6,225 feet above mean sea level, Lake Tahoe is one of the largest high-altitude lakes in the world. The clarity and purity of its water are outstanding. In fact, protection of quality of the water in Lake Tahoe is a primary objective for effective control of the region's environment.

The spectacular scenery of the Lake Tahoe Region results from unique geological conditions that prevailed when the lake was formed. The basement rock is predominantly granite related to the rocks found throughout the Sierra Nevada. On the other hand, the geologic structure – the faulting that produced the lake basin itself – is related to the Basin Ranges that extend eastward from the Sierra to the Wasatch Range in Utah. The lake was formed by a natural dam – a great pile of andesitic mudflow breccia – across the north outlet.

Lake Tahoe is on the eastern boundary of that part of the Sierra Nevada that was extensively glaciated during the Pleistocene epoch. Huge valley glaciers moved down canyons along the western side of the lake, scouring away loose rock and building up great piles of morainal debris. Along the eastern side, glaciers developed only on the shaded side of the highest peaks; so most of this area was not glaciated. This accounts for the subdued rolling topography typical of the Carson Range, as contrasted to the rugged Sierran crest on the west side of the basin.

Climate of the region is strongly influenced by topography. Marine air from the Pacific Ocean, 150 miles to the west, drops its moisture (mostly as snow) as it rises over the crest of the Sierra. Average annual precipitation ranges from more than 50 inches on the western side of the region to about 25 inches along much of the eastern shoreline. The Weather Bureau at Tahoe City, on the west side, reports long-term average snowfall of 213 inches. The fairly long summers are comparatively cool; mean maximum temperature at Tahoe City in July over a 50-year period was 78°F. Winters are cold but seldom severe; mean daily minimum temperature for January over the same period was 17°F. The high elevation and cool temperatures result in a short growing season – an average of only 70 to 120 frost-free days per year at various points near the Lake.

Vegetation includes desert, montane, and alpine species typical of the eastern slopes of the Sierra. Pine and fir forests were heavily logged between 1860 and 1900 when demand for lumber and props for the Nevada silver mines was high. Even so, today the region has good stands of conifers between the Lake level and 9,000 feet, plus considerable areas covered by chaparral and other brush. On fairly level open areas that have a few inches of soil, grasses and other herbage flourish during the short growing season.

Numerous species of wildlife inhabit the Lake Tahoe Region. Deer, bear, mountain lion, coyote, rabbit, raccoon, and several rodents are common. Land birds and waterfowl are present in small numbers consistent with available habitat. Heavy commercial fishing in the Lake around 1900 depleted native populations of cutthroat trout and whitefish, but kokanee salmon and several species of fish stocked from state hatcheries provide good recreational fishing today. Numerous tributary streams also provide sport fishing.

Soils are generally shallow and highly erodible – easily disturbed and slow to stabilize – but the soil is fairly deep in some bottom lands and glacial debris areas. The varied climate and highly erodible soils combine to make the Lake Tahoe region a fragile environment. Hence the ecological balance is easily upset. Whenever vegetation is removed, it is not soon replaced. Erosion by wind and water is a constant hazard; it damages pristine features of the Lake, including the spawning areas of native fish.

Changing Environment

Before the white man began settling in this area about the middle of the 1800's, the somewhat nomadic Washo Indian tribe inhabited it. Their name for the lake, "Tahoe," has been variously translated as "big water," "high water," or "water in a high place." The first recorded white visitors were John Fremont's exploring party (1844); they were soon followed by the Forty-niners and other western migrants and adventurers.

During most of the following 100 years, Lake Tahoe was the summer recreation area for wealthy Californians, mostly from San Francisco and the Sacramento Valley. The few summer resorts, scattered stores, service stations, and restaurants hardly marred the natural beauty of the region.

Soon after World War II all this began to change. With increased general affluence, steadily and rapidly increasing numbers of vacationers began to visit the area; their visits gradually extended the "season" from summer to the full year. Establishment of year-round casinos at Stateline in 1955 and the phenomenal growth of winter sports added to the influx of both visitors and residents. By unofficial count in 1965, the region had nearly 29,000 yearlong residents – more than double the 1960 federal census figure. Present projections anticipate more than 50,000 residents by 1980 and an added summer population topping 250,000.

These projected increases in resident and transient populations will inevitably multiply and intensify the environmental problems that already are plaguing the area. Hence the crucial need for planning orderly development that can be sustained by the natural capacities of the region.

Administrative and Governmental Responsibility

The Planning Area established by the Bi-State Planning Compact between the States of California and Nevada is a basin covering 327,878 acres including the 122,628 acres of lake surface. Governmental jurisdiction over land in the Lake Tahoe Planning Area is complex (table 1). The area is divided between California (Placer, El Dorado, and Alpine counties) and Nevada (Washoe and Douglas counties and Carson City). This division of governmental responsibility makes it difficult to coordinate the administration of government in the Area in the interest of protecting the environment.

Nearly half (48.7 percent) of the land area is federally owned – chiefly in three National Forests totalling 107,762 acres. An additional 4.5 percent is state owned, nearly all in State Parks. Thus about 53 percent of the land in the Planning Area is publicly owned.

Of nearly 75 miles of lake shoreline, about 18 percent is publicly owned. This is chiefly 8 miles belonging to the State of California and 5.5 miles in National Forests.

Tahoe Regional Planning Agency (TRPA)

The Tahoe Regional Planning Agency began work as soon as the governors of California and Nevada signed the proclamation creating the Bi-State Planning Agency. Public Law 91-148 had enumerated the dangers of deterioration of the natural environment at Tahoe and of the increasing demands on various natural resources and features of the Region; also, it emphatically stated the need to maintain equilibrium between the Region's natural endowment and limitations on one hand and the

Table 1. – Land acreage, by jurisdiction, Lake Tahoe Regional Planning Area, February 1971

Jurisdiction	Gross acreage	Federal land acreage[1]	State park acreage	Private land acreage
Federal:				
Eldorado N. F.	85,518			
Tahoe N. F.	12,060			
Toiyabe N. F.	10,184			
Bur. of Reclamation	64			
	107,826	107,826		
State:				
California	3,552		3,552	
Nevada	6,047		6,047	
	9,599		9,599	
Counties and Cities:				
Alpine	4,170	4,170	0	0
El Dorado	96,887	81,348	3,535	12,004
Placer	46,291	12,124	17	34,150
Washoe	19,700	2,731	3,020	13,949
Douglas	23,538	6,619	709	16,210
Carson City	5,830	834	2,318	2,678
South Lake Tahoe City	5,482	0	0	5,482
Total land area	201,898	107,826	9,599	84,473
Lake Tahoe area[2]	122,628			
Small lakes area	3,352			
Total, Lake Tahoe Region Planning Area	327,878			

[1] *National Forest land except 64 acres in Placer County controlled by the Bureau of Reclamation.*
[2] *At legal elevation of 6,229.1 feet above mean sea level.*

environment that man is creating. It recognized need for establishing "an area-wide planning agency with powers to adopt and enforce a regional plan of resource conservation and orderly development, to exercise effective environmental controls, and to perform other essential functions . . . "

TRPA was ordered to develop and adopt, within 18 months of its formation (i.e., by September 1971), a plan for regional development that would include separate plans for land use, transportation, conservation, recreational development, and public services and facilities, to name a few. The Agency was further directed to consider and to seek to harmonize the needs of the whole Region with the plans of local governmental units and the existing land use plans of State and Federal agencies.

Since nearly half of the land area in the Lake Tahoe Region is in National Forests, the Forest Service has major responsibility for improving environmental features here. In 1970 it established

the Lake Tahoe Basin Planning Team to work with TRPA. Although the Agency and Team have separate organizations and responsibilities, they have cooperated closely to achieve a common goal.

Climate has critical importance to planning and development of the Lake Tahoe Region. Schools, recreation areas, and other public facilities must be located in amenable places, not in wind gaps or shaded zones. Feasibility of revegetating disturbed building sites and roadsides is strongly influenced by levels of temperature and precipitation, especially the extremes of these variables. Soil erosion, streambank cutting, and flooding all result from the amount, intensity, and timing of precipitation. Foreknowledge of these factors can help prevent problems and hazards.

The capacity of various parts of the Lake Tahoe Basin to assimilate or disperse the air pollutants associated with auto exhaust, incineration, and wood smoke depends partly upon wind flows and vertical air currents. Wind erosion of exposed ground is a major source of dust in the air and hence sediment that ultimately is borne to streams and the Lake. Clarity of the air – so important to enjoyment of the Lake Tahoe environment – must be improved and maintained.

Unfortunately for the planning task at hand, fairly little long-term information about weather and climate in the Tahoe Basin is available, and the volume of short-term information is small. Cooperative Weather Bureau stations at Glenbrook and Tahoe City have operated for many years. At Incline Village, volunteer observers have recorded temperatures and precipitation for the past few years. A recording station at Tahoe Valley Airport has observations that are most useful for aeronautical purposes but they do not include data on such phenomena as vertical air currents and precipiation; moreover, the location of the airport in the narrow neck of Lake Valley is such that its measurements of surface winds do not represent general conditions in the Basin. The Coast Guard Station at Tahoe City has recorded visual wind observations, temperature, and precipitation only since 1967. Early records of precipitation at Bijou and Tallac are available, and records of temperatures and precipitation at Meyers for the past few years are available (3)[1]. These fragmentary records are useful, but to a limited degree.

Of importance to the present planning project is the study of Lake Tahoe Basin climate started in 1968 by Dr. John W. James (6, 7). This study utilizes 14 weather stations, operated by Dr. James and cooperative observers; they record temperatures, precipitation, evaporation, relative humidity, and barometric pressure.

During the late 1960's, basic monitoring of air pollution was conducted at two locations; its records provide a partial picture of the worsening air pollution at Lake Tahoe (8). Monitoring over the Labor Day weekend in 1970 with modern instrumentation provided a more precise picture of the situation than earlier measurements had (2).

The following Precipitation Map shows the location of climatological and air pollution recording stations.

This publication is intended to: 1. summarize climatological data that are available; 2. interpret these data, insofar as is possible, so that they may be useful in regional planning; and 3. recommend procedures that would help ameliorate such environmental problems as erosion, snow damage, devegetation, floods, and air pollution, where climate is such an important determinant.

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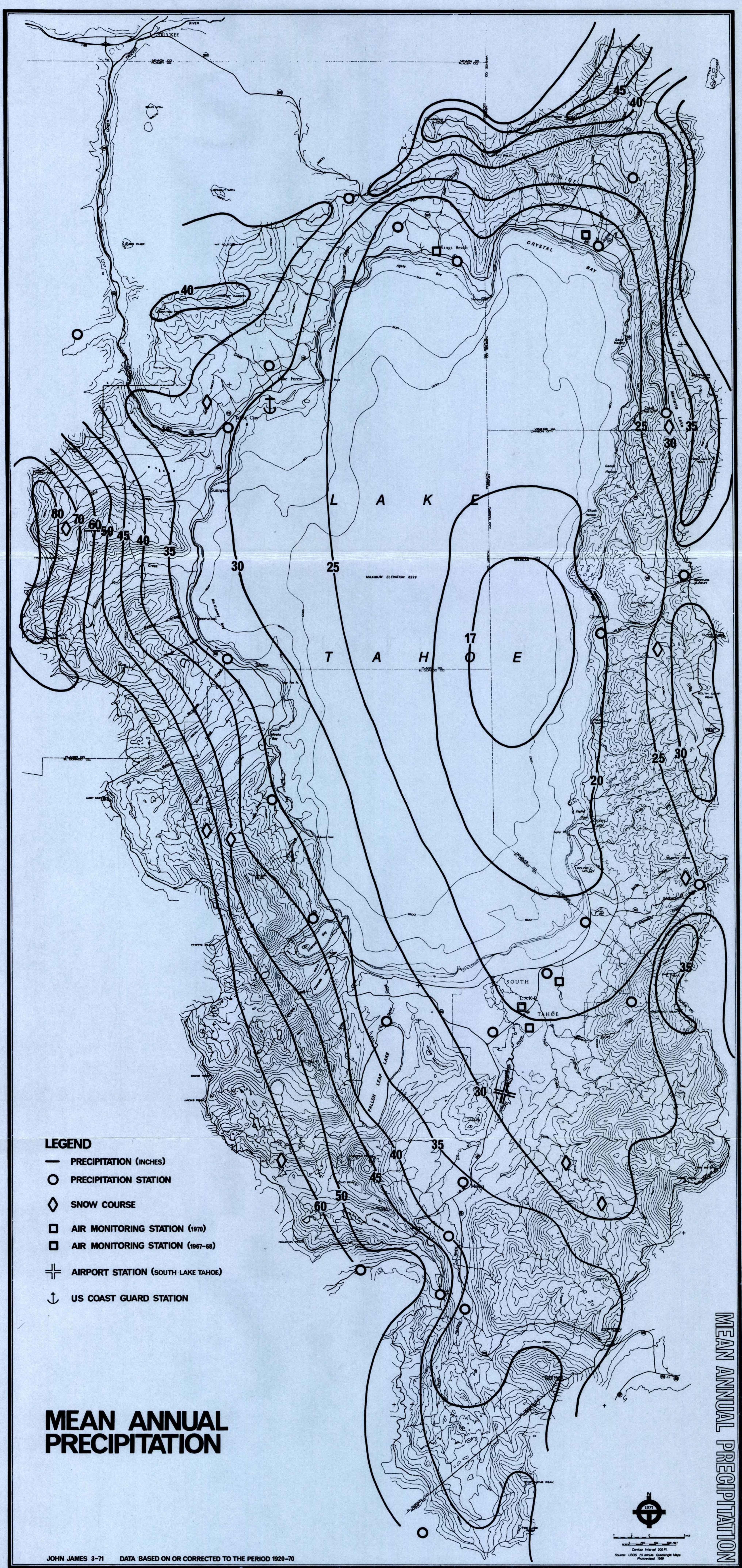
[1] *Numerals in parentheses refer to correspondingly numbered items in the References section, p. 31.*



LAKE TAHOE REGION

TAHOE REGIONAL PLANNING AGENCY

USDA FOREST SERVICE

CLIMATE OF THE LAKE TAHOE BASIN

In general study of the climate of the Lake Tahoe Basin it is necessary to keep in mind not only factors influencing the basin as a whole (e.g. seasonality and regional storms), but also variations in climate between the east and west shores, and between high and low elevations.

PRECIPITATION AND TEMPERATURE

Because of the summer-dry, winter-wet precipitation regime of the Sierra Nevada, the cold season corresponds to the wet season in the Lake Tahoe Basin, and most of the precipitation is snow. Approximately 55 to 70 percent of the average annual precipitation (rain and snowfall water content) falls during the 4-month period of December through March (figs. 1, 2, and 3). At elevations below 6,500 feet, about 75 to 80 percent of this precipitation normally is snow; at elevations of 8,000 feet and higher, approximately 90 to 95 percent of winter precipitation is snow (fig. 4).

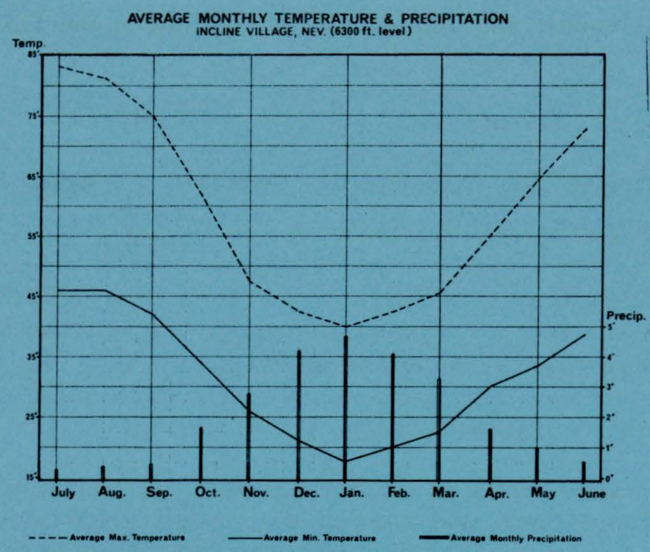
At elevations below 6,500 feet the snow season (when a continuous snow cover is present) usually begins early in December and continues into early or mid-April. At altitudes above 8,000 feet the snow season is somewhat longer – from early November to early or mid-May (table 2 and (9)). The snow cover period varies considerably from year to year; the periods shown in Table 2 are only averages. Also, the snow cover period varies within the Basin: part of the east shore occasionally has a partially "bare ground" winter (see "Climatic Regions" below).

Despite the snowy winters, temperatures in the Lake Tahoe Basin are comparatively mild; daytime high temperatures during January average 35-40° F. at lower elevations. Nighttime low temperatures vary much more because of topographic complexity; but they generally range from the low teens to low 20's. These temperatures, all mild for this elevation, can be attributed to: 1. The high amount of winter sunshine – about 55 to 60 percent of total possible hours; 2. the comparatively mild Pacific air masses that enter the area in winter; 3. the high elevation and consequently clean upper air that allows maximum insulation; 4. the "heat reservoir" characteristics of the Lake in winter (i.e., the Lake is warmer than the surrounding land because of the thermal character of the water in contrast to that of the land); and 5. the low-level temperature inversion that is common at night in the Tahoe Basin, which confines more extreme low temperatures to the lowest levels away from the lake (see table 3 for contrasted minimum temperatures at selected points in the Basin).

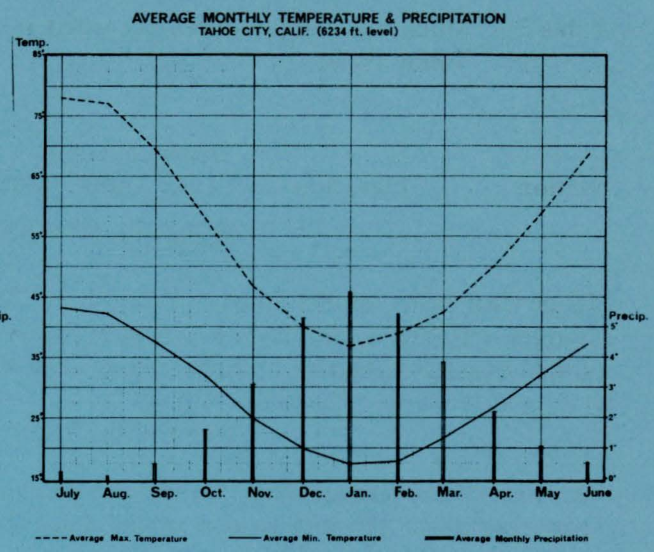
The warmer zone, 150 to 400 feet above the Basin, and the much colder Upper Lake Valley, are also distinguished by the length and severity of cold temperatures during the year (table 4).

The preceding map of the Lake Tahoe Basin, showing mean annual precipitation, shows the wettest area is in the northwest, where total precipitation by some estimates averages more than 70 inches. This wet node, wetter than areas of like elevation directly to the south, is due, possibly, to the depressed topography of the American River Basin to the southwest. Whereas the Crystal Range disrupts the southwesterly flow of moisture-laden air into the higher ground in western and southwestern areas of the Basin, this is not true for the Barker Pass-Twin Peaks area.

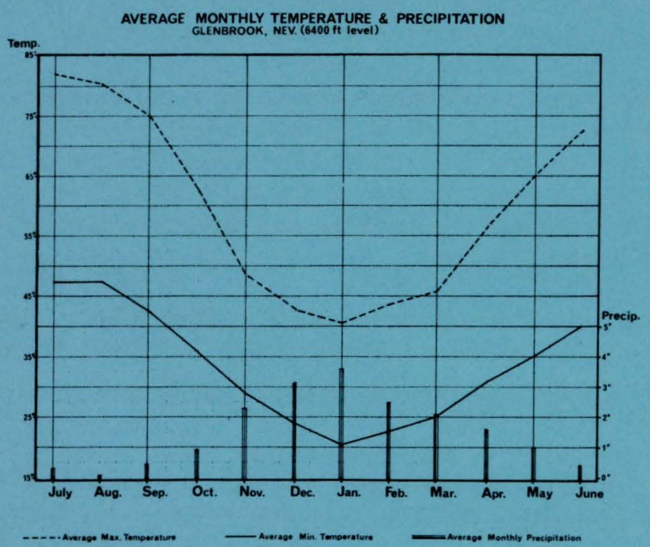
The driest portion of the Basin area is adjacent to the central east shore, where annual averages are less than 18 inches. At this point, in the lee of (i.e., northeast of) the Crystal Range, the rainshadow effect is most pronounced. Occasionally the normal west-east movement of storms stalls in the Great Basin (western Nevada portion), and the counterclockwise circulation of air around the un-



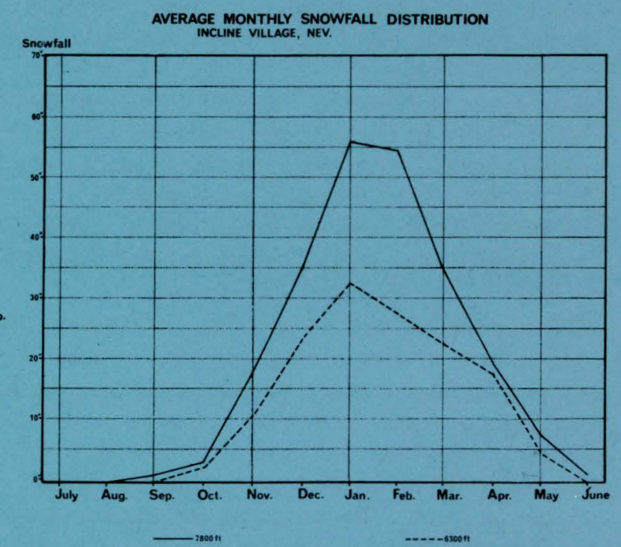
(Fig. 1)



(Fig. 2)



(Fig. 3)



(Fig. 4)

Table 2. – Earliest and latest dates for selected depths of snow on the ground at 8,000 feet, west shore of Lake Tahoe Basin

Depth of snowpack (Inches)	Earliest dates: Actual recorded	Earliest dates: Average	Latest dates: Actual recorded	Latest dates: Average
5	Sept. 23	Nov. 4	June 14	May 25
10	Oct. 2	Nov. 15	June 12	May 22
20	Nov. 10	Dec. 13	June 9	May 19
30	Nov. 11	Dec. 25	June 5	May 12
50	Nov. 20	Jan. 12	May 26	May 1
60	Dec. 6	Jan. 27	May 22	Apr. 22

Table 3. – Minimum temperatures recorded in January and July at selected stations in the Lake Tahoe Basin

Station	Elevation	Distance from Lake Tahoe	January Average	January Absolute	July Average	July Absolute
	(Feet)	(Miles)	(°F.)		(°F.)	
Tahoe City	6,230	0	17	-14	43	30
Stateline (SLT)	6,250	1/2	16	-17	42	30
Incline Village	6,350	1/2	18	-5	46	34
Meyers	6,350	6	11	-28	41	27
Glenbrook	6,475	1/3	21	-2	47	35

Table 4. – Average number of consecutive days when temperatures exceeded listed temperatures at selected weather stations

Station	Temperatures 16°	20°	24°	28°	32°
Glenbrook	–	–	181	144	129
Tahoe City	238	198	175	125	83
Meyers (Upper Lake Valley)	210	168	126	77	18

stable low pressure area produces an upslope condition over the Carson Range, giving that area the heaviest precipitation.

Precipitation at Lake Tahoe varies greatly from year to year for two reasons. One is that the area is fairly far to the south of the Gulf of Alaska wintertime storm breeding area and the jet stream track. Also, more than half of the winter half-year precipitation frequently falls in 12 to 14 days, but not consecutive days. Tables 5 and 6 show that winter precipitation can be heavy in the Basin. Complete data on precipitation in El Dorado and Nevada Counties are published by the U. S. Weather Bureau in the County Summaries.

Although evaporation at the Lake has been measured infrequently – and never in the winter half-year – it is apparent that summertime evaporation (not pan evaporation) is nearly as great as winter half-year (November-April) precipitation. For example, at Meyers, summer half-year actual evaporation averages 36.44 inches, and winter half-year precipitation is 34.59 inches. Volumes of evaporation vary greatly, influenced by slope, aspect, and vegetative cover; but most areas in the Lake Tahoe Basin that average less than 35 to 45 inches of annual precipitation lose more water by evaporation than they receive from precipitation.

Table 5. – Nine-day cumulative precipitation recorded at Tahoe City and Twin Lakes, December 23 through 31, 1964

	Tahoe City	Twin Lakes
Day	**inches**	**inches**
1	6.77	4.33
2	9.77	6.77
3	10.60	7.18
4	11.55	8.40
5	12.92	10.92
6	14.27	13.73
7	14.57	14.74
8	15.50	15.99
9	17.33	18.20

Notes:

1. Tahoe City is near the level of the Lake (about 6,225 ft.), but Twin Lakes, near the extreme southwest corner of the Basin, is at an elevation of about 7,850 feet.
2. The 8-day total for Tahoe City, shown above, was approximately two-thirds of normal annual precipitation.

Table 6. – Monthly precipitation at three weather stations, December 1955 through February 1956

Station	**Dec. 1955**	**Jan. 1956**	**Feb. 1956**	**Total**	**Percent of average annual**
	- - - - - - - - - - - - - - *Inches*	- - - - - - - - - - - - -			
Tahoe City	22.77	12.93	4.27	39.97	132
Meyers	30.08	14.29	5.11	49.48	126
Glenbróok	12.77	6.90	3.10	22.77	127

CLIMATIC REGIONS

The Lake Tahoe Basin can be divided into four broad climatic regions, as described below.

Region I. Lower elevation East Shore (Tahoe Vista to East South Lake Tahoe); below the 7,000 to 7,200-foot elevation

Characteristics:

1. Less than 25 inches average annual precipitation
2. Infrequent heavy precipitation
3. 150 to 200 inches average annual snowfall; occasional partially "bare-ground" winters

4. Warm summer days: average high temperatures of 75° to 85°. Mild summer nights: low temperatures in mid to high 40°'s. "Mild" winter nights: low temperatures from high teens to low 20°'s
5. Occasional moderate winds, especially from the southwest and west in winter; from northwest and west in summer, and lighter velocities.

Region II. Higher elevation East Shore; above 7,000 to 7,200-foot elevation

Characteristics:

1. Precipitation of 25 to 35 inches; as much as 45 inches in extreme northeastern corner of area.
2. Occasional heavy precipitation
3. 200 to 280 inches average annual snowfall
4. Cool summer days: average high temperatures low to mid-70°'s

   Mild summer nights: low temperatures from high 30°'s to low 40°'s

   Cool winter nights: low temperatures in low to mid-teens.
5. Occasional strong winds, especially southwesterly and westerly and occasionally easterly in winter; northwesterly and westerly in summer, and lighter velocities
6. Rime ice conditions occasionally in winter above 8,000 feet during stormy periods

Region III. Lower elevation West Shore (Carnelian Bay to West South Lake Tahoe); below 7,000 to 7,200-foot elevation

Characteristics:

1. Average annual precipitation of 30 to 40 inches
2. Occasional heavy precipitation in winter
3. 200 to 325 inches average annual snowfall; partially "bare-ground" winters are unusual
4. Cool, mild summer days: average high temperatures in mid to high 70°'s

   Mild summer nights: low temperatures from high 30°'s to low 40°'s

   Cool winter nights: low temperatures in mid to high teens
5. Occasional moderate winds, especially from the southwest and west

Region IV. Higher elevation West Shore; above 7,000 to 7,200-foot elevation

Characteristics:

1. Average annual precipitation of 40 to 60 inches (as much as 80 inches in northwest corner of area)
2. Heavy precipitation frequent in winter
3. 325 to 450 inches average annual snowfall
4. Cool summer days: average high temperatures in high 60°'s to low 70°'s

   Cool summer nights: low temperatures from high 30°'s to low 40°'s

   Cool winter nights: low temperatures in low and mid-teens

5. Occasional strong winds, especially from the southwest and west in winter, northwest and west in summer, and lighter velocities
6. Rime ice conditions common in winter above 8,000 feet during stormy periods.

These "regions" are necessarily rather general and somewhat overlapping, but are used here as a convenience and as a possible first step toward considering the entire Lake Tahoe Basin as being composed of identifiable subregions, each by its climatic situations and problems.

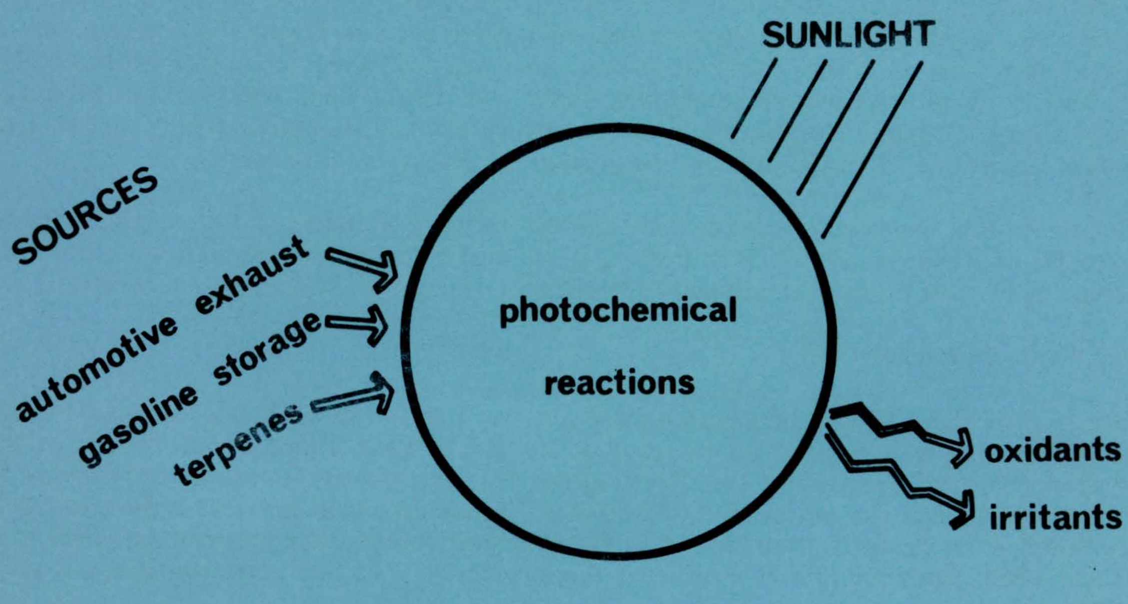
In Regions I and III, immediately adjacent to the Lake, year-round nighttime temperatures are cooler than in nearby land areas. Also, lakeside locations have lower daytime temperatures in summer and higher temperatures in winter than areas further from the Lake. In the summer half-year (May-October), areas below about 6,650 feet have atmospheric conditions conducive to collection of air pollutants. In the winter half-year (November-April), during stable inter-storm periods, the area below about 6,400 feet is a potential pollution-collecting area, but for shorter periods of time than in summer.

THE PROBLEM OF AIR POLLUTION

CAUSES

Motor vehicle engines produce some particulate matter, nitrogen oxides, lead, carbon monoxide, and various hydrocarbons. The components of auto and truck exhausts, together with naturally produced terpenes, react with sunlight to form haze, nitrogen dioxide, ozone, and a variety of compounds that irritate eyes and damage some plants. Although considered unlikely, the possibility cannot be ruled out that ozone could also reach the ground surface by subsidence from the upper atmosphere. Visible pollution is frequently observed from incinerators, backyard burning, fireplaces, construction and road dust, slash burning, and asphalt batch plants. Smoke from these can easily be seen when it is trapped beneath the inversion layer on summer mornings and occasionally in the winter. Particulate matter from these combustion sources is generally rich in carbonaceous matter that is identifiable by its appearance and odor when collected on filter mats, by analysis of the total carbon content, or by the quantities of organic matter extractable with a solvent such as benzene. Combustion can also cause the particulate matter to contain sulfates and nitrates.[2] Together with organics, these can cause respiratory irritation. Gas heating of buildings can be a source of nitrogen oxides, but it is not especially important as a producer of visible particulate matter.

All the ingredients for the photochemical smog reaction exist at Lake Tahoe. The principal difference between Lake Tahoe and other areas of California is that at Lake Tahoe a larger proportion of ultraviolet light is available to accelerate the reaction. The proportion of ultraviolet light is increased here by the high altitude and the lesser thickness of atmosphere overlying the region.



(Fig. 5)

[2] *Ash particles from combustion of wood contain probably less than 1 percent of sulfates.*

SIGNIFICANCE

Primary damage from air pollution is the reduction of visibility and the obscuration of scenery and views across the Lake. If air pollution is allowed to worsen, damage to forest trees and to landscaped areas can be expected. The concentration at which serious damage begins to occur is not yet known. Except for wind-blown dust, which is now a recognizable problem, air pollution is not yet so serious as to cause health problems. However, a potential for causing adverse health effects from air pollution definitely exists. Since the temperature inversions at Tahoe are at low level, the emitted pollutants are concentrated into a smaller total volume of air, and the peak concentration produced can be higher than that found in areas where the inversion may range from 2,000 to 5,000 feet in depth. The ultimate volume and concentration of air pollution will, of course, depend on total population, land use, and combustion practices for cooking, heating, transportation, incineration, and open burning.

EVIDENCE

Measurements of air quality in the Lake Tahoe Basin have been very limited in both scope and duration. Ozone was measured throughout 1967 and 1968. Ozone and particulate matter were measured in September 1970.

Ozone measurements, 1967-68

Two Lake Tahoe stations, South Lake Tahoe and Incline Village, were included in the Interstate Surveillance Network Program administered by the National Air Pollution Control Administration Division of Abatement (5). The rubber cracking test was used for measuring ozone in terms relative to this test (4). This index is specific and very sensitive for ozone and in this case provided the average concentrations for each week. Data for 1967-1968 are in table 7.

Because the data from the two stations were not substantially different, we plotted their averages for the two years together (fig. 6). A striking seasonal pattern appears. Ozone was detected only in the May-October period. Some peaks in ozone concentration were associated with holiday weekends, the most pronounced of which was Labor Day 1967. Since ozone is also produced naturally, especially at higher elevations and by subsidence from aloft, meteorological factors need to be assessed to identify their separate contributions to the observed ozone levels.

There is no doubt that increased ozone levels are also associated with increased motor vehicle traffic in the Lake Tahoe Basin; therefore, all sources of ozone merit very careful evaluation lest the situation become intolerable from the combined contributions of natural and man-produced ozone.

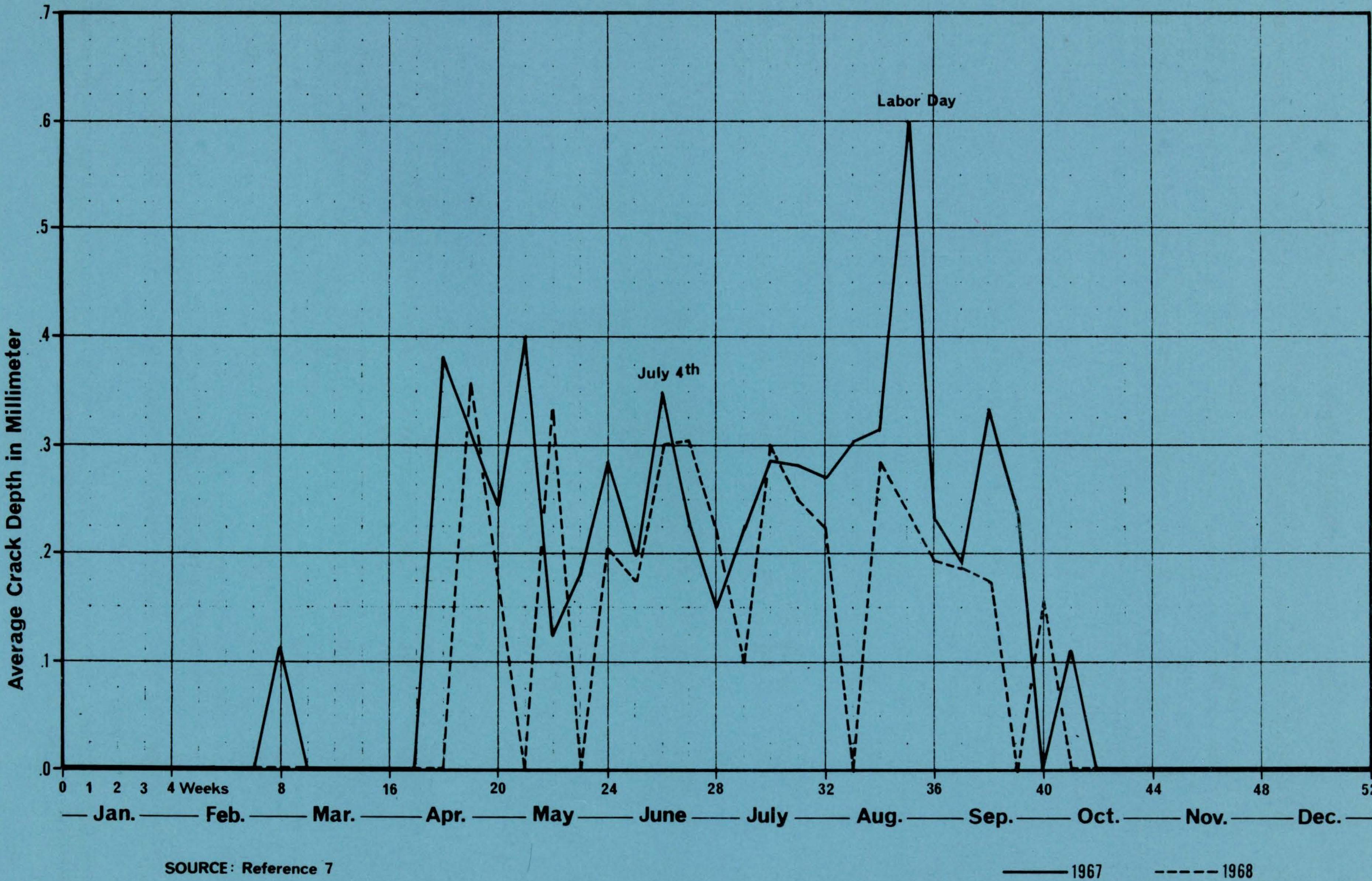
Labor Day Week, September 1970

Air quality was measured at two sites within the Basin over Labor Day week, September 4 through 8, 1970. Instruments were located on the roof of the South Lake Tahoe Police Station at the intersection of Fremont Avenue and Tree Haven Drive. This site, three blocks south of Highway 50 and the lakeshore, is near the center of the South Lake Tahoe urbanized area and is the area represented by South Lake Tahoe Station No. 96 in the Interstate Surveillance Program data presented for 1967 and 1968. Sampling probes were located approximately 12 feet above the Police Station parking lot.

On the North Shore, sampling was conducted at Kings Beach Fire Station at the intersection of California Highway 267 and Highway 28. Instruments were placed on the roof of the Fire Station about 20 feet off the ground.

At both these sites particulate matter was collected by continuous filtration through glass fiber mats at 30 to 60 cubic feet per minute for 24 hours. The collected material was weighed and analyzed for

PRESENCE OF OZONE AS DETERMINED BY RUBBER CRACKING
SOUTH LAKE TAHOE AND INCLINE VILLAGE
(AVERAGED BY WEEK)



SOURCE: Reference 7

(Fig. 6)

Table 7. – Presence of ozone determined by rubber cracking, Lake Tahoe, 1967 and 1968

(Average crack depth in millimeters)

	1967			1968		
Week	South Lake Tahoe	Incline Village	Average*	South Lake Tahoe	Incline Village	Average*
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	–	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	.232	.116	0	0	0
9	0	0	0	0	0	0
10	–	0	0	0	0	0
11	–	0	0	0	–	0
12	–	0	0	–	–	–
13	–	0	0	–	–	–
14	–	0	0	0	–	0
15	–	0	0	0	–	0
16	–	0	0	0	–	0
17	0	0	0	0	–	0
18	–	.381	.381	0	–	0
19	–	–	–	High	.359	.359
20	.287	.207	.247	0	0	0
21	.400	–	.400	0	0	0
22	.260	0	.130	.297	.363	.330
23	.340	.025	.183	0	0	0
24	.285	.290	.288	.257	.159	.208
25	.406	0	.203	.204	.141	.173
26	.139	.562	.351	.373	.206	.295
27	.206	.262	.234	.267	.340	.304
28	.302	0	.151	.274	.192	.233
29	.260	.200	.230	.206	0	.103
30	.358	.218	.288	.324	.295	.310
31	.277	.285	.281	.298	.207	.253
32	.292	.242	.267	.187	.271	.229
33	.325	.287	.306	0	0	0
34	.270	.363	.317	.262	.312	.287
35	.542	.653	.598	.207	.269	.238
36	.479	0	.240	.219	.178	.199
37	.373	0	.187	.321	.061	.191
38	.365	.302	.334	0	.342	.171
39	.486	0	.243	0	0	0
40	0	0	0	0	.311	.156
41	.230	0	.115	0	0	0
42	0	–	0	0	0	0
43	0	–	0	0	0	0
44	0	0	0	0	–	0
45	0	0	0	0	–	0
46	0	0	0	0	–	0
47	0	0	0	0	0	0
48	0	0	0	0	–	0
49	0	–	0	0	–	0
50	0	–	0	0	–	0
51	0	–	0	0	0	0
52	0	–	0	0	0	0

**When one measurement was missing, value recorded at other station was used for average.*
Source: See (5).

its lead, sulfate, nitrate and benzene extractable organic content. Grab samples of air were analyzed for carbon monoxide and hydrocarbons. Total oxidant (mostly ozone) was determined at the South Shore site by using a continuous amperometric analyzer, which was calibrated dynamically just before and after the study period.

Particulate Matter

At both stations particulate matter was collected on pre-weighed glass fiber mats by filtering about 2000 m^3 of air in 24-hour periods. Table 8 summarizes the sampling periods and findings. From the data on particulate matter, which is the most complete of all the data taken, both geographic and temporal factors can be discerned. Air quality differences between the North and South Shores are clearly apparent. Two distinct patterns were evident at each sampling station during the September 4 - 8 sampling period. First, the total concentrations of suspended particulate matter were consistently higher at the South Shore, sometimes by as much as a factor of 2. Second, substantially more suspended particulate matter was measured at both stations on September 4 and 5 than during the other 24-hour sampling periods.

This difference from the other days is associated with very high winds on September 4 and 5 that were followed by a snow storm. Associated with the high wind was visible dustiness. The very much higher pollution at the South Shore was consistent with greater opportunities to create windblown dust there. On the other days during that period the concentrations of particulate matter were near or somewhat higher than the minimums observed at urban stations in the United States. Concentrations of sulfates, nitrates, lead, and organics were all within ranges found at urban locations. They were consistently as high as or higher than maxima observed for characteristically nonurban stations. This comparison signifies that a substantial man-caused component contributed to the air quality at Tahoe.

A clue to what particular activities contribute pollution is evident from the ratios of the components with respect to total particle weight and with respect to the lead concentration (table 8). At the North Shore the lead concentration remained remarkably constant at 0.5 $\mu g/m^3$. It did not increase during September 4 - 5; this confirmed the windblown origin of the increased particulate matter. The lead content of the atmosphere at the South Shore was generally somewhat less than that of the North Shore. The notable exception was a peak in lead concentration during the 24-hour period between Sunday morning and Monday morning, September 6 and 7. This peak appears to be related to the increased motor vehicle traffic during the holiday weekend. The percentage of lead in the particulate matter is consistent with that of urban samples except for September 4 to 5, when it was much lower; that was when a greater proportion of the particles was wind-blown dust.

In contrast to lead, the organics in $\mu g/m^3$ were consistently higher at the South Shore. Differences between NO_3 and SO_4 were too small to determine their significance. With respect to total particulate matter, the organics tended to be higher in the south. Like lead, they show an interesting pattern over the sampling period, with peaks on September 5 to 6 and September 6 to 7. When comparing ratios of sulfates, nitrates, and organics with respect to lead (table 8), the ratios for sulfates and organics are substantially higher in the south.

The particulate matter on the filters, especially on samples for September 5 - 6 and September 6 - 7, was very black and had a characteristic odor of smoke from pine wood. The high content of sulfates and organics could have come from this source. The greater volume of fire smoke would be expected from the more heavily populated South Shore. Analysis of fire smokes could confirm this. Because one would expect motor vehicle traffic to be in proportion to the relative populations at the South and North Shores, higher lead values would have been expected in the South. Fire smoke is usually emitted as particles larger than the lead-containing particles from cars. Therefore, the lead-containing particles are likely to be distributed more widely by advection, throughout the region, whereas the larger smoke particles are likely to be confined more closely to the areas where the smoke was produced.

Table 8. – Particle concentration and chemical composition*, Lake Tahoe Basin, Labor Day weekend, 1970

			Concentration ($\mu g/m^3$)				As % of total mass Concentration				Ratio to Lead		
South Lake Tahoe	Day	Total particles	$SO_4=$	NO_3-	Org.	Pb	$SO_4=$	NO_3-	Org.	Pb	$SO_4=$	NO_3-	Org.
Filter No. 21	Sep. 4	252.2	5.46	0.86	9.56	0.23	2	0.3	4	0.1	24	4	42
23	5	62.7	7.0	1.12	9.1	0.37	11	2	15	0.6	19	3	25
25	6	61.8	4.9	1.26	13.9	0.61	8	2	22	1.0	8	2	23
27	7	65.2	5.88	1.40	7.5	0.30	9	2	12	0.5	20	2	25
Kings Beach													
Filter No. 22	Sep. 4	110.0	6.72	1.96	9.0	0.50	6	2	8	0.5	13	4	18
24	5	47.0	4.76	1.12	8.1	0.53	10	2	17	1.1	9	2	15
26	6	38.0	5.18	1.25	5.8	0.52	14	3	16	1.4	10	2	11
28	7	41.1	5.46	1.12	4.6	0.59	13	3	11	1.6	9	2	8

**Determined by analysis of HiVol samples by the Air and Industrial Hygiene Laboratory, California State Dept. of Public Health, for the Air Resources Board, State of California. Each sample was collected during a 24-hour period, approximately 0800 - 0800.*

The evaluation of particulate matter points to windblown dust, home or open fires, and motor vehicles as major sources of pollutants that should be subjected to control.

Gaseous components

Grab samples of air were taken in plastic bags according to the schedule recorded in table 9. They were taken several times a day at the South Shore, but only once daily at Kings Beach. These were analyzed within a few days by nondispersive infrared, which has a lower limit of detection at about 2 ppm. During September 6 and 7, samples were taken simultaneously in evacuated stainless steel cylinders only at the South Shore and were analyzed several months later by gas chromatography, a technique that is sensitive down to the sub-ppm range. The samples were also analyzed for non-methane hydrocarbons which, like CO, are generally produced by motor vehicles (table 10).

The CO peaks occurred near midday and midnight concomitant with non-methane hydrocarbons. Separate analyses of mixing depths and traffic flow are required to explain the midnight peaks. Even though the levels are well below those prescribed by the California ARB air quality standards, these data leave no doubt that motor vehicle traffic measurably degrades air quality in the Lake Tahoe Region.

The oxidant values, presumably mostly due to ozone, measured continuously by the amperometric instrument at South Shore, also show striking diurnal patterns. These reveal peaks occurring in the afternoon usually following the midday peak of carbon monoxide. This finding confirmed an expectation of photochemical formation of ozone resulting from ultraviolet radiation acting on motor vehicle exhausts. During this study period the afternoon oxidant peaks never exceeded 6 pphm; i.e., they were below ARB air quality standards of 10 pphm for 1 hour and at the proposed federal standards for 6 pphm for 1 hour.

The other striking features of the oxidant patterns were the recurring nighttime peaks. Between September 3 and 4 this peak reached 9 pphm (fig. 7). The source for this remains unclear. The phenomenon of nighttime peaks has been observed in other regions of the United States. Since they coincided with the nighttime peaks of CO (figs. 7 and 8), the source is consistent with subsidence or downflow of pollutants concentrated in the inversion layer during the day. At that time, ozone could have been formed photochemically. To what extent this ozone was formed in nature is sub-

Table 9. – Carbon monoxide concentration* in Lake Tahoe Basin, Labor Day Weekend (Sept. 4 - 8), 1970

Day	Time (PST)	Concentration
	South Lake Tahoe Police Station	
Sept. 4		ppm
(Friday)	0820	2.0
	1158	2.0
	1650	2.5
	2010	2.5
Sept. 5		
(Saturday)	0830	1.5
	0928	6.0
	1230	2.0
	1557	5.0
Sept. 6		
(Sunday	0840	3.5
	1145	3.0
	1330	5.5
	1730	3.5
	2055	8.5
Sept. 7		
(Monday)	0745	8.0
	1250	3.0
	1930	2.0
	2225	1.0
Sept. 8		
(Tuesday)	0815	2.0
	Kings Beach Fire Station	
Sept. 4		
(Friday)	1015	2.5
Sept. 5		
(Saturday)	0950	3.5
Sept. 6		
(Sunday)	1000	4.0
Sept. 7		
(Monday)	1000	3.0
Sept. 8		
(Tuesday)	1315	3.5

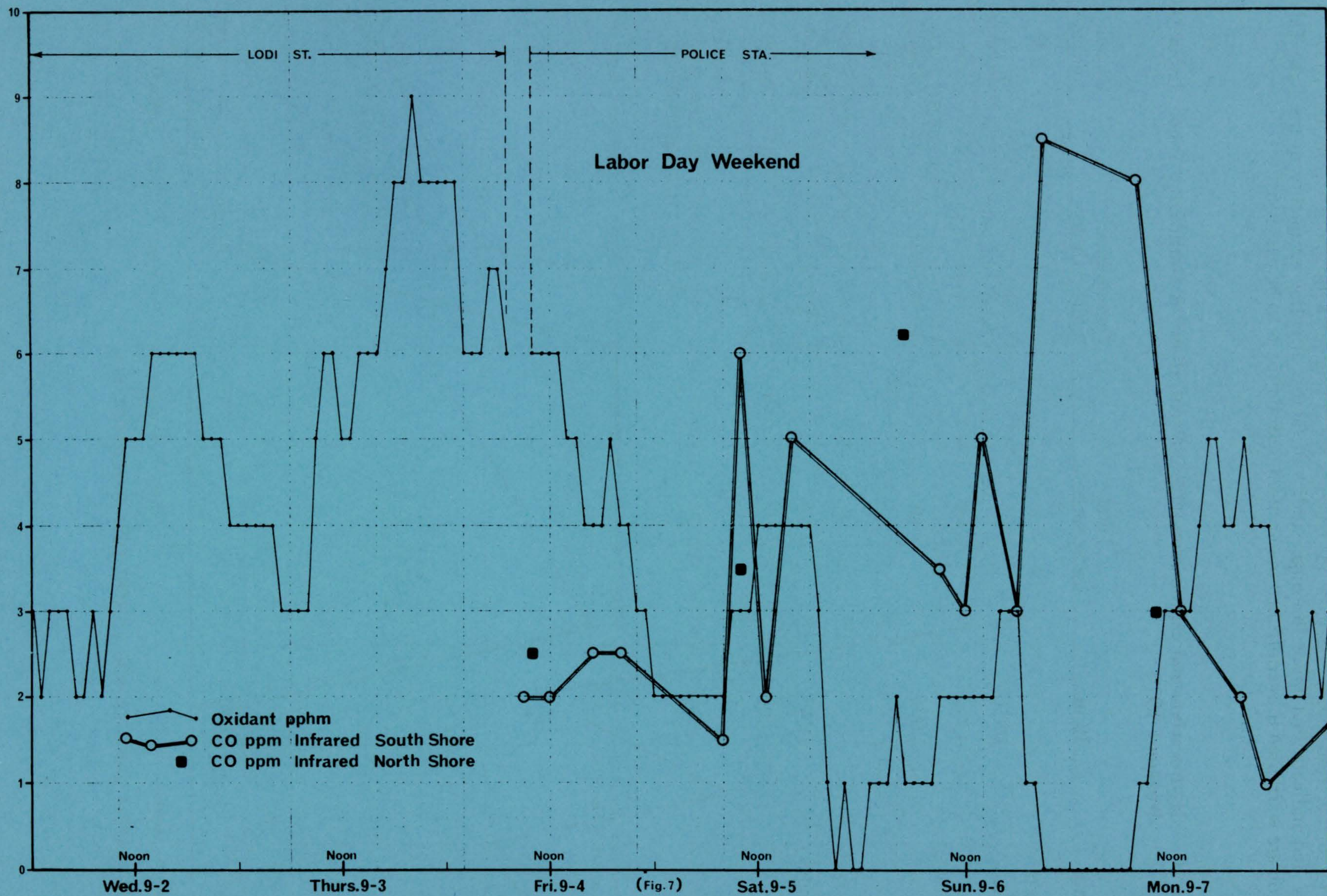
**Determined by nondispersive infrared analysis by State of California, Air Resources Board.*

ject to further research. These data on oxidants are consistent with findings from the 1967-1968 study and indicate that more thorough studies of factors affecting air quality in the Lake Tahoe Region are warranted if uncontrolled man-caused degradation is to be prevented.

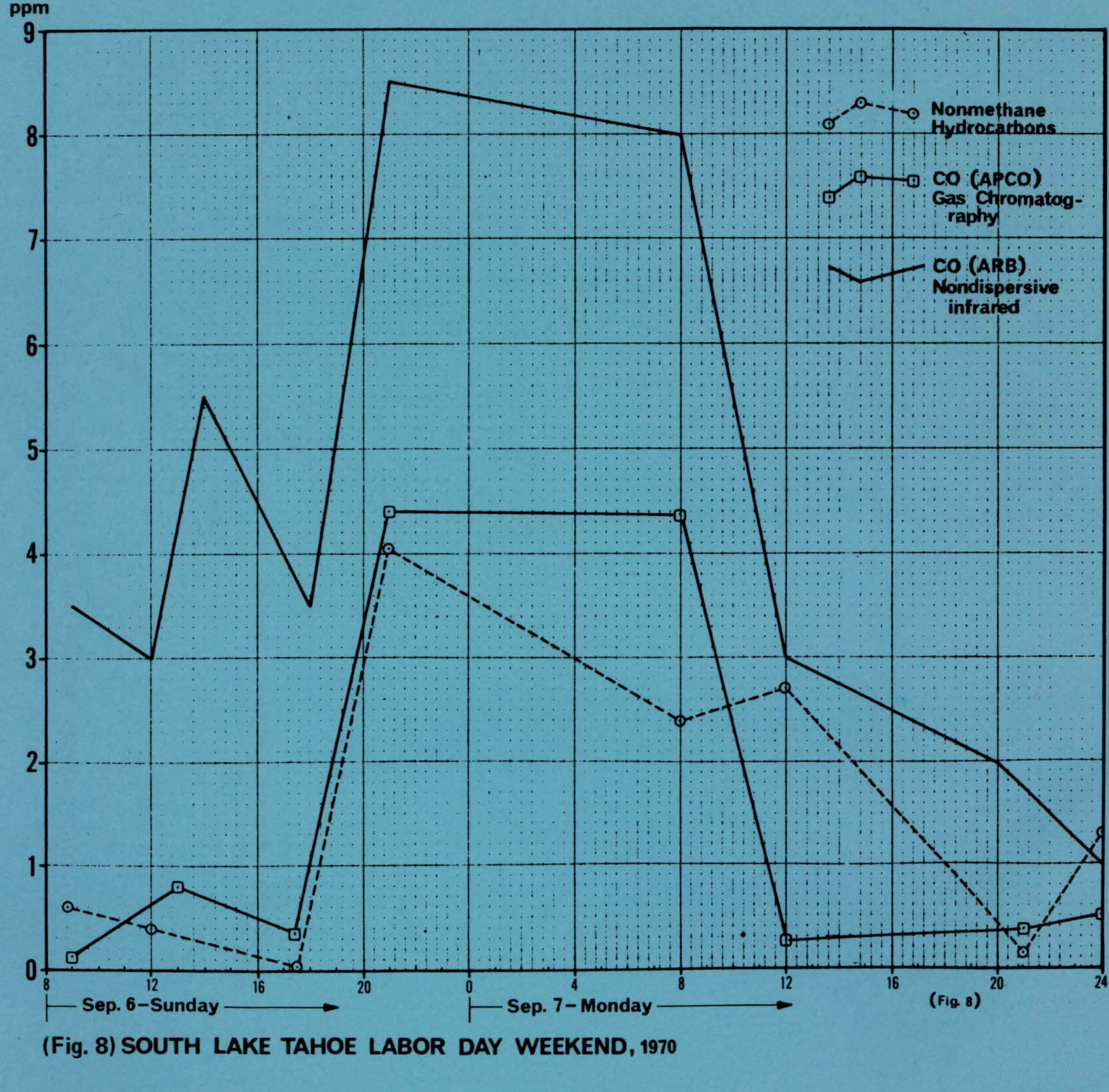
Table 10. – Hydrocarbon and carbon monoxide concentration* at South Lake Tahoe, Labor Day Weekend, 1970

Date	Hour	Total hydrocarbons	Non-methane hydrocarbons	Carbon monoxide
Sept. 6				
(Sunday)	0850	2.1	0.60	0.10
	1730	1.43	0.05	0.30
	2055	6.65	4.10	4.40
Sept. 7				
(Monday)	0745	4.35	2.35	4.35
	1200	4.15	2.69	0.30
	1930	1.52	0.12	0.30
	2225	2.8	1.30	0.45

**Concentration determined by gas chromatographic analysis by the Chemistry and Physics Division, Air Pollution Control Office, Environmental Protection Agency.*



(Fig. 7) TOTAL OXIDANT AND CARBON MONOXIDE CONCENTRATION



(Fig. 8) SOUTH LAKE TAHOE LABOR DAY WEEKEND, 1970

WIND AND THE POTENTIAL FOR AIR POLLUTION[3]

The most stable atmospheric conditions with the least wind movement occur during night and early morning hours in summer and fall and occasionally in dry winter months. Stable atmospheric conditions and light breezes prevail during almost every nonstorm night because of nocturnal radiation and drainage-wind effects. These stable conditions probably occur during night and early morning about 225 to 250 days a year; the number is slightly more in a drought year and slightly less in a wet year. Under these conditions locally generated air pollution is trapped.

Trapped pollutants would not be dispersed until solar heating brought about degradation of inversion conditions and onset of an afternoon breeze. The east shore and the eastern part of Tahoe Valley would be the last to experience the changes described above because of the shadowing effect of the eastern rim of mountains. On average summer days, solar heating would begin dispersion by 0730 to 0830 PST and probably would complete dispersion of pollutants by 1000 to 1030 PST. During winter pollution days, the low angle of the sun would require a longer time to heat up the cold layer of air near the ground and disperse pollutants. The months of June through October have the most frequent nocturnal inversions – averaging 15 to 20 days per month. Mixing depth ranges from less than 500 to as much as 2,000 feet, and usually averages only 150 to 400 feet.

On rare but increasingly frequent occasions, smog actually flows into the Lake Tahoe Basin from the Sacramento Valley. Under special weather conditions, when little vertical mixing of air and turbulence are associated with steady westerly winds, smog is blown up to the 8,000-foot elevation and over the rim of the Lake Tahoe Basin. Once in the summer of 1968, visibility across the Lake was reduced to only 4 miles despite a steady west wind estimated at 20 miles per hour.

If air conditions worsen outside the Basin, they may well have deleterious effects on the Basin itself despite its regional controls.

[3] *This section is based on the report by Gordon Bell (1).*

WIND CIRCULATION

Because of Lake Tahoe Basin's elevation and the nature of the mountain ridges that surround it, air circulation within the basin can be assessed by considering the interaction between topographic configurations and various wind directions.

Lake Tahoe itself provides a flat bottom to the basin, which has an area of 191 square miles. Along the Lake's east shore, mountains rise rather steeply from the comparatively narrow coastal fringe. This contrasts with the more gradual rise to the ridges west of the Lake. Winds from the south through west probably are more than half of all nonstorm winds. Wind that blows at speeds of 7 to 12 m.p.h. during midday provides ample ventilation of the Basin.

Winds from the northeast, east, and southeast are a much smaller fraction of wind occurrences. The eastern and southeastern coastal fringes of the Lake provide some topographic sheltering. When these winds blow, shoreline areas just east of Brockway (north shore) and in Tahoe Valley (south shore) may experience local wind circulation that provides less dispersive atmospheric conditions than those that characterize the remainder of the Basin.

Tahoe City Coast Guard Station

Table 11 is a quarterly seasonal summary of frequency of wind direction based on twice-daily observations (0700 or 0800 PST and 1400 PST) taken at the U. S. Coast Guard Station at Tahoe City (Lat. 39° 10.5′ N., Long. 120° 9′ W) from January 1967 through September 1969. This eight-compass-point presentation was developed from observations made to 36 points. At the morning observation, calms occurred most frequently during the summer quarter (60.4%) and the winter quarter (43.5%), and exceeded calms in the spring quarter (19.5%) and the fall quarter (19.6%) by factors of 3 and 2, respectively. In the spring, prevailing wind directions are southwest and south (40.3%). In summer, fall, and winter, wind direction occurrences from slightly west of north account for 12.1%, 37.7%, and 43.0%, respectively. During summer, winds from the southwest quadrant account for 16.1% of frequencies, and for 24.1% in the fall. Sheltering by the mountain ridges to the northeast, east, and southeast is evidenced by the low frequencies of these wind directions.

During the afternoon, winds from the southwest sector dominate in all seasons: 34.0% in spring, 29.7% in summer, 31.2% in the fall, and 32.3% in winter.

Wind speeds recorded at the Coast Guard Station at 0700 or 0800 PST are summarized by season in table 12; records for observations at 1400 PST are reported similarly in table 13.

During morning hours, calms and wind speeds less than 6 knots (7 m.p.h.) account for the largest percentages: spring, 67.6%; summer, 81.9%; fall, 83.9%, and winter 78.8%. Thus, in the summer, fall, and winter seasons, the early morning hours are most likely to have ineffective ventilation by wind, storm conditions excepted.

During the afternoon, wind speeds increase. Speeds in excess of 6 knots (7 m.p.h.) account for 54.6% in spring, 63.9% in summer, 59.2% in fall, 50.6% in winter. In spring and winter there is only

Table 11. – Frequency of wind direction by seasonal quarter, Tahoe City Coast Guard Station, January 1967 – September 1969

(Highest frequencies shown in boldface)

Wind direction	SPRING Freq.	SPRING Rel.%	SUMMER Freq.	SUMMER Rel.%	FALL Freq.	FALL Rel.%	WINTER Freq.	WINTER Rel.%
				Observation at 0700-0800 PST				
N	30	12.4	**33**	**12.1**	**75**	**37.7**	**89**	**43.0**
NE	7	2.9	2	0.7	3	1.5	3	1.4
E	6	2.5	3	1.1	2	1.0	–	–
SE	27	11.2	12	4.4	11	5.5	–	–
S	40	16.6	12	4.4	22	11.0	5	2.4
SW	**57**	**23.7**	26	9.5	26	13.1	8	3.9
W	19	7.9	18	6.6	14	7.0	7	3.4
NW	8	3.3	2	0.7	7	3.5	5	2.4
Calm	47	19.5	**165**	**60.4**	39	19.6	90	43.5
Σ	241	100.0	273	99.9	199	99.9	207	100.0
				Observation at 1400 PST				
N	4	1.9	4	1.5	15	8.1	5	3.0
NE	–	–	2	0.7	2	1.1	3	1.8
E	–	–	6	2.2	4	2.2	4	2.4
SE	37	17.7	40	14.9	19	10.2	20	12.2
S	47	22.5	44	16.4	35	18.8	31	18.9
SW	**71**	**34.0**	**80**	**29.7**	**58**	**31.2**	**53**	**32.3**
W	31	14.8	68	25.3	24	12.9	28	17.1
NW	4	1.9	5	1.8	5	2.7	5	3.0
Calm	15	7.2	20	7.4	24	12.9	15	9.2
Σ	209	100.0	269	99.9	186	100.0	164	99.9

Source: Gordon Bell (1).

about equal chance that winds will increase in speed above 5 knots (6 m.p.h.) during afternoon hours.

Tahoe Valley Airport

Wind observations between 0700 PST and midnight at Tahoe Valley Airport (Lat. 38° 54′ N., Long. 120° 00′ W., Elev. 6,273 feet) during 1965, 1966, and 1967 are summarized in tables 14 and 15. Topographic barriers to the west and east tend to funnel winds into this portion of Tahoe Valley from the north or south. Table 14 shows the average wind speed and prevailing wind directions for the odd-numbered hours beginning at 0700 PST in January, April, July, and October.

The lowest average hourly wind speeds in summer months (e.g., July) occur at 0700 PST and again in the late evening. The Tahoe Valley Airport observer reported smoke layers aloft at estimated heights of 500 to 800 feet during the evening and early morning hours in summer and fall.

Table 12. – Frequency of wind speeds by speed classes observed at Tahoe City Coast Guard Station, January 1967 through September 1969

(Observations at 0700 - 0800 PST)

Season	*Knots*						
	Calm	2-5	6-10	11-15	16-20	$\geqq 21$	Total
SPRING							
1967	34	28	14	5	8	2	91
1968	–	54	21	7	4	–	86
1969	13	34	8	6	1	2	64
Total	47	116	43	18	13	4	241
Rel.%	19.5	48.1	17.8	7.5	5.4	1.7	
SUMMER							
1967	61	26	5	–	–	–	92
1968	42	41	5	3	1	–	92
1969	62	19	6	1	1	–	89
Total	165	86	16	4	2	–	273
Rel.%	60.4	31.5	5.9	1.5	0.7		
FALL							
1967	20	59	2	6	4	–	91
1968	5	57	13	2	–	–	77
1969[a]	14	12	4	1	–	–	31
Total	39	128	19	9	4	–	199
Rel.%	19.6	64.3	9.5	4.5	2.0		
WINTER							
1966-67[b]	5	45	5	1	2	1	59
1967-68	60	8	9	4	1	–	82
1968-69	25	20	14	3	1	3	66
Total	90	73	28	8	4	4	207
Rel.%	43.5	35.3	13.5	3.9	1.9	1.9	

[a] *September only.*
[b] *January and February 1967 only.*
Source: Gordon Bell (1).

Table 13. – Frequency of wind speeds by speed classes observed at Tahoe City Coast Guard Station, January 1967 through September 1969

(Observations at 1400 PST)

Season	Knots						
	Calm	2-5	6-10	11-15	16-20	21	Total
SPRING							
1967	7	18	11	17	8	3	64
1968	--	37	24	13	7	--	81
1969	8	25	13	13	3	2	64
Total	15	80	48	43	18	5	209
Rel. %	7.2	38.3	23.0	20.6	8.6	2.4	
SUMMER							
1967	6	22	32	25	5	1	91
1968	4	26	29	25	7	--	91
1969	10	21	33	15	7	1	87
Total	20	69	94	65	19	2	269
Rel. %	7.4	25.7	34.9	24.2	7.1	0.7	
FALL							
1967	19	17	25	11	4	1	77
1968	3	30	30	11	4	1	79
1969[a]	2	5	16	5	2	--	30
Total	24	52	71	27	10	2	186
Rel. %	12.9	28.0	38.2	14.5	5.4	1.1	
WINTER							
1966-67[b]	14	7	9	7	4	2	43
1967-68	1	36	15	7	4	1	64
1968-69	--	23	16	14	3	1	57
Total	15	66	39	28	11	5	164
Rel. %	9.1	40.2	23.8	17.1	6.7	3.0	

[a] *September only.*
[b] *January and February 1967 only.*
Source: Gordon Bell (1).

Table 14. – Average speed and prevailing direction of winds at odd-numbered hours observed at Tahoe Valley Airport in selected months of 1965, 1966, and 1967

Month		Hour (PST) 07	09	11	13	15	17	19	21	23	Avg.
January	Knots	4.8	5.2	5.7	9.1	8.7	5.1	3.6	5.0	4.4	5.4
	Dir.	S-SE	S-SE	S	N-S	N-S	S-SW	S-SE	S	S-SE	
April	Knots	4.8	7.4	9.5	10.4	9.9	9.0	6.1	4.8	5.6	7.5
	Dir.	S-SE	S	S	N-S	N-S	S-SW	S-SW	S	S-SE	
July	Knots	1.7	6.1	10.3	9.7	9.8	9.6	6.2	2.6	2.1	6.2
	Dir.	S-SE	N-SW	N-S	S-SW	S-SW	S-SW	S	S	S	
October	Knots	3.6	3.5	7.3	8.9	8.2	4.4	3.7	3.3	3.3	5.1
	Dir.	S-SE	S	N	N-S	N-S	S-SW	S-SE	S-SE	S-SE	

Source: Gordon Bell (1).

Table 15. – Frequency of wind directions at Tahoe Valley Airport for mid-season months of 1965, 1966, and 1967

(Based on hourly observations from 0700 to 2300 PST)

Wind direction	January Freq.	Rel. %	April Freq.	Rel. %	July Freq.	Rel. %	October Freq.	Rel. %
N	**182**	**12.1**	**235**	**15.4**	**277**	**17.5**	**275**	**17.4**
NE	10	0.7	34	2.2	33	2.1	38	2.4
E	14	0.9	18	1.2	9	0.6	14	0.9
SE	135	9.0	52	3.4	52	3.3	102	6.4
S	**422**	**28.2**	**553**	**36.1**	**432**	**27.3**	**405**	**25.6**
SW	98	6.5	**226**	**14.8**	**261**	**16.5**	114	7.2
W	8	0.5	35	2.3	10	0.6	13	0.8
NW	62	4.1	52	3.4	43	2.7	114	7.2
Calm	570	38.0	325	21.2	463	29.4	506	32.1
Σ	1501	100.0	1530	100.0	1580	100.0	1581	100.0

Frequencies and percentages for primary and secondary directions are in boldface.
Source: Gordon Bell (1).

Records show that a breeze blowing from the north and north-northwest begins about 1230 PST in winter and late fall, at about 1030 PST in the spring and early fall, and at about 0930 PST in the summer. During spring and summer months, when clouds build up over ridges surrounding Tahoe Valley, the attendant cooling of the mountain slopes causes a reversal of the wind direction. These winds blow from the south and southwest and are also typical of the nighttime drainage winds in spring and summer, as well as the storm wind directions in fall and winter. This accounts for the dominance of the frequencies shown for the south, southeast, and southwest in table 15. These southerly directions account for 43.7% of the wind in January, 54.3% in April, 52.1% in July and 39.2% in October. The northerly lake breeze is most frequent in the early fall (when cloudiness is least); north and northwest winds account for 24.6%.

Lake breezes blow 20.2 percent of the time in summer, 18.8 percent in spring, and 16.2 percent in winter. Most of the wintertime frequency represents post-frontal wind conditions. Calms average 21.2 percent in spring, 29.4 percent in summer, 32.1 percent in fall, and 38.0 percent in winter. Observations at Tahoe Valley Airport report as "calm" all winds less than 4 knots (4.5 m.p.h.); consequently the "calm" frequencies recorded there also include all very light wind conditions, which can spread visible pollution over rather large areas within the Basin.

Atmoshperic Stability

In the absence of temperature profile measurements for determination of atmospheric stability, an inferred stability index can be calculated with an empirical equation that uses surface temperatures (1). E. H. Markee, Jr., of the U. S. Public Health Service, and H. W. Baynton used such an equation in reporting relations between measurements of stability and air quality when they reported results of the famous Detroit-Windsor study in the mid-1950's[4]. The stability index is calculated by summing algebraically the mean of consecutive daily maximum temperatures, the mean temperature for the 24-hour period, and the change in maximum temperature. It is expressed symbolically thus:

$$S.I. = \frac{1}{2}(T_{x1} + T_{x2}) - Tm + (T_{x2} - T_{x1})$$

where T_{x1}= Yesterday's maximum
T_{x2}= Today's maximum
Tm = Mean of today's minimum and maximum

The values calculated from temperature records for 2 3/4 years from the Coast Guard Station at Tahoe City have a range of values from -3 to +31. The data were tabulated with respect to the following classes:

	Index value
Very stable:	25 to 31
Stable:	18 to 24
Neutral:	11 to 17
Unstable:	4 to 10
Very unstable:	-3 to 3

Table 16 shows the frequency of stability index occurrences. Results show that summer quarter has the highest incidence of days (47.4 percent) with stable atmospheric conditions. Fall quarter, with 38.0 percent stable days is next; spring has 26.9 percent, and winter quarter shows only 16.4 percent of days having stable atmospheric conditions. All these measurements and calculations point to one certainty: summer and fall quarters provide the most likely conditions for poor dispersion of air pollutants during morning and late evening hours.

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[4]*It is not claimed here that the index can be used with confidence in the Lake Tahoe Basin; hence, improved indices and measurements should be sought.*

Table 16. – Frequency of stability class occurrences observed at Tahoe City Coast Guard Station, January 1967 through September 1969

Season	Year	Very Stable	Stable	Neutral	Unstable	Very Unstable	TOTAL
SPRING	1967	2	23	23	23	16	87
	1968	–	19	42	15	6	82
	1969	–	16	29	7	2	54
Total		2	58	94	45	24	223
Rel.%		0.9	26.0	42.2	20.2	10.8	223
SUMMER	1967	–	43	40	7	2	92
	1968	3	34	40	10	5	92
	1969	3	46	29	7	3	88
Total		6	123	109	24	10	272
Rel. %		2.2	45.2	40.1	8.8	3.7	
FALL	1967	3	23	48	13	4	91
	1968	5	25	27	12	3	72
	1969[a]	2	15	8	4	–	29
Total		10	63	83	29	7	192
Rel. %		5.2	32.8	43.2	15.1	3.6	
WINTER	1966-67[b]	–	8	35	7	9	59
	1967-68	1	11	31	24	10	77
	1968-69	1	7	13	5	9	35
Total	1968-69	2	26	79	36	28	171
Rel. %		1.2	15.2	46.2	21.1	16.4	

[a] *September only.*
[b] *January and February 1967 only.*
Source: Gordon Bell (1)